Defense Technical Information Center Compilation Part Notice

ADP013921

TITLE: Symbolic Computation Techniques for Aperture Antennas

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: 2002 International Conference on Mathematical Methods in Electromagnetic Theory [MMET 02]. Volume 2

To order the complete compilation report, use: ADA413455

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP013889 thru ADP013989

SYMBOLIC COMPUTATION TECHNIQUES FOR APERTURE ANTENNAS

Niyazi Ari, Ahmet Y. Tesneli*, S. Selim Seker**, Osman Cerezci*

University of Applied Sciences Zurich, Dept. of Applied R&D,
Technoparkstr 1 CH-8005, Zurich, E-mail: nari@fhzh.ch

*Sakarya University, Dept. of El-Electr. Eng, 54187 Esentepe, Sakarya, Turkey
E-mail: atesneli@sakarya.edu.tr, E-mail: cerezci@sakarya.edu.tr

**Bogazici University, Dept. of El-Electr. Eng, 80815 Bebek, İstanbul, Turkey
E-mail: seker@boun.edu.tr

ABSTRACT

Symbolic Computations are very important since to get closed formula solutions in many applications. One of the computer code is MACSYMA that is written in program language LISP for the performing symbolic and numeric mathematical manipulations. The purpose of this paper is to present a number of MACSYMA applications that show how the new MACSYMA possibilities can be used in electromagnetics. To understand the procedure easily, rectangular aperture antenna analysis has been studied and the results have been illustrated.

SYMBOLIC COMPUTATION OF A RECTANGULAR APERTURE

The analysis of apertures begins by considering the radiation from the elemental area oriented in the x=0 plane as shown in Figure 1. The elemental area is part of some arbitrary aperture bounded by the curve C. The spherical coordinates of the elemental area is $(r', \pi/2, \theta')$ and the fields are to be evaluated at the point $P(r, \phi, \theta)$.

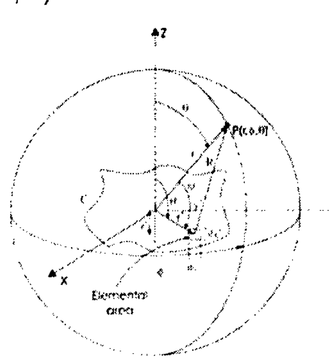


Figure 1. Elemental area

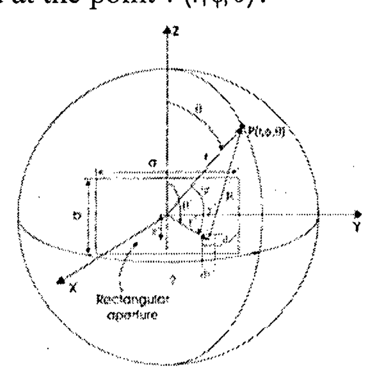


Figure 2. Rectangular aperture

Since the elemental area being analyzed can be excited by both electric and magnetic fields, It is convenient to use both the magnetic and electric vector potentials[2]. Therefore, the magnetic (**A**) and electric (**F**) vector potentials become, respectively

```
(c1) (declare([\a,\f,\j,\m,\n,\l,\e,n,\e1,\h1], nonscalar), depends([\n,\l], [rp,phip,thetap]))$
(c2) \a:vect_express(mu*exp(-%i*k*r)*\n/(4*%pi*r),spherical);
```

(d2)
$$\left[\frac{\mu e^{-ikr} N_r}{4\pi r}, \frac{\mu N_\phi e^{-ikr}}{4\pi r}, \frac{\mu e^{-ikr} N_\theta}{4\pi r}\right]$$

```
(c3) \f:vect_express(epsilon*exp(-%i*k*r)*\l/(4*%pi*r));
```

(d3)
$$\left[\frac{\varepsilon e^{-ikr} L_r}{4\pi r}, \frac{\varepsilon L_\phi e^{-ikr}}{4\pi r}, \frac{\varepsilon e^{-ikr} L_\theta}{4\pi r}\right]$$

where **N** and **L** are the radiation vectors. The far electric field from the electric and magnetic vector potentials becomes

```
(c4) \e:vect_express(-%i*w*\a-%i*w/k^2*grad(div(\a))+curl(\f)/epsilon)$
(c5) (\e:ev(\e,diff),\e:expand(\e));
```

(d5)
$$\left[-\frac{\mu e^{-ikr} N_0 \cos(\theta)\, w}{4\pi k r^2 \sin(\theta)} + \frac{i\mu e^{-ikr} N_0 \cos(\theta)\, w}{2\pi k^2 r^3 \sin(\theta)} + \frac{i\mu e^{-ikr} N_r w}{2\pi k^2 r^3} - \frac{L_\phi e^{-ikr} \cos(\theta)}{4\pi r^2 \sin(\theta)}, \right.$$
$$\frac{ike^{-ikr} L_0}{4\pi r} - \frac{i\mu N_\phi e^{-ikr} w}{4\pi r},$$
$$\left. \frac{i\mu e^{-ikr} N_0 \cos^2(\theta)\, w}{4\pi k^2 r^3 \sin^2(\theta)} - \frac{i\mu e^{-ikr} N_0 w}{4\pi r} + \frac{i\mu e^{-ikr} N_\theta w}{4\pi k^2 r^3} - \frac{ikL_\phi e^{-ikr}}{4\pi r}\right]$$

Since the far field distance is large, terms which vary inversely with the distance can be ignored compared to the other terms so that for the far electric field

```
(c6) (\e:[0,\e[2],part(\e,3,[2,4])],\e:subst(mu=k*\z0/w,\e),\e:undistrib(\e)):
```

(d6)
$$\left[0, \frac{ike^{-ikr}\left(L_0 - N_\phi Z0\right)}{4\pi r}, -\frac{ike^{-ikr}\left(N_\theta Z0 + L_\phi\right)}{4\pi r}\right]$$

A rectangular aperture of finite dimensions can be analyzed in terms of the elemental area. Consider an aperture in the x=0 plane with sides of lengths a and b in the y and z directions, respectively, as shown in Figure 2. Let the electric field be aligned with the y axis and the magnetic field be aligned with the z axis to give a plane wave traveling in the x direction. If the aperture is uniformly illuminated, the electric field is constant in amplitude and phase over the aperture. For this case, the electric and the magnetic surface current densities are

```
(c7) (n:[1,0,0], \e1:[0,\e0,0], \h1:[0,0,\e0/\z0],\j:vect_express(n~\h1), \m:vect_express(-n~\e1))$
```

The radiation vectors for the rectangular aperture become

```
(c8) (rp:[0,yp,zp], ar:[sin(theta)*cos(phi),sin(theta)*sin(phi),cos(theta)])$
(c9) \n:integrate(integrate(\j*exp(%i*k*vect_express(ar,rp)),yp,-a/2,a/2),zp,-b/2,b/2)$
     Is   k sin(ϕ) sin(θ)   zero or nonzero?
     nonzero

(c10) \l:integrate(integrate(\m*exp(%i*k*vect_express(ar,rp)),yp,-a/2,a/2),zp,-b/2,b/2)$
     Is   k sin(ϕ) sin(θ)   zero or nonzero?
     n
(c11) t:[sin(theta)*cos(phi),-sin(phi),cos(theta)*cos(phi);sin(theta)*sin(phi),cos(phi),sin(phi)*cos(theta);cos(theta),0,-sin(theta)]$
(c12) (\n:\n.t, \l:\l.t)$
```

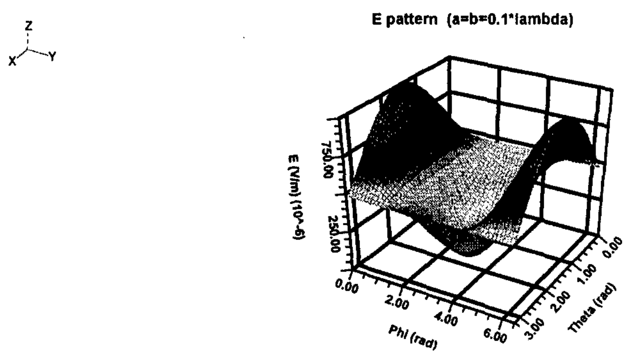
The far electric field vector is obtained as

```
(c13) \e:[0,%i*k*exp(-%i*k*r)*(\I[3]-\n[2]*\z0)/(4*%pi*r),-%i*k*exp(-%i*k*r)*(\n[3]*\z0+\I[2])/(4*%pi*r)]$
(c14) (\e:expand(\e),\e:trigexpand(\e),\e:expand(\e),\e:undistrib(\e));
```

(d14)
$$\left[0, \frac{i\, e^{-ikr}\left(\frac{\cos(\phi)}{\sin(\theta)}+1\right)\sin\left(\frac{b\,k\cos(\theta)}{2}\right)\sin\left(\frac{a\,k\sin(\phi)\sin(\theta)}{2}\right)E0}{\pi\, k\sin(\phi)\, r\cos(\theta)}, \frac{i\, e^{-ikr}\sin\left(\frac{b\,k\cos(\theta)}{2}\right)\sin\left(\frac{a\,k\sin(\phi)\sin(\theta)}{2}\right)E0}{\pi\, k\, r\sin(\theta)}\right]$$

The electric field pattern is

```
(c15) (e:sqrt(abs(part(\e,2))^2+abs(part(\e,3))^2),e:trigsimp(e))$
(c16) define(\e(phi,theta),subst(part(e,1,1,1)=(1+cos(phi)*sin(theta))^2,e))$
(c17) (lambda:1, \e0:1, r:10*lambda, k:2*%pi/lambda, a:.1*lambda, b:.1*lambda)$
(c18) plot3d(\e(phi,theta),theta,.0001,%pi-.0001,phi,.0001,2*%pi-.0001,"Theta (rad)","Phi (rad)",
      "E pattern  (a=b=0.1*lambda)"),zlabel:"E (V/m)",plotnum0=50,plotnum1=50,plot_style=scientific3d$
```



CONCLUSION

Symbolic computation results of a uniformly illuminated rectangular aperture have been obtained and the electric field pattern have been illustrated as a numerical example. So, how the symbolic computation techniques can be applied to electromagnetics has been shown.

REFERENCES

[1] "Macsyma Mathematics and System Reference Manual", 16th ed., Macsyma, Inc., USA, 1996.

[2] WOLFF, Edward A., "Antenna Analysis", John Wiley & Sons, Inc., USA, 1966.